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Gemstone deposits of Serbia

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Abstract: Gemstone minerals in Serbia have never been regarded as an interesting and significant resource. Nevertheless, more than 150 deposits and occurrences have been recorded and some of them preliminarily explored in the last 50 years. The majority of deposits and occurrences are located within the Serbo-Macedonian metallogenic province and the most significant metallogenic units at the existing level of knowledge are the Fruška Gora ore district, Cer ore district, Šumadija metallogenic zone, Kopaonik metallogenic zone and Lece-Halkidiki metallogenic zone. The most important genetic type of deposits is hydrothermal, particularly in case of serpentinite/peridotite as host/parent rock. Placer deposits are also economically important. The dominant gemstones are silica minerals: chalcedony (chrysoprase, carnelian, bluish chalcedony etc.), jasper (picture, landscape, red etc.), common opal (dendritic, green, milky white etc.), silica masses (undivided), and quartz (rock crystal, amethyst etc.). Beside silica minerals significant gemstones in Serbia include also beryl (aquamarine), garnet (almandine and pyrope), tourmaline, fluorite, rhodochrosite, carbonate-silica breccia, carbonate-silica onyx, silicified wood, howlite, serpentinite, marble onyx, and kyanite. This paper aims to present an overview of Serbian gemstone deposits and occurrences and their position based on a simplified gemstone metallogenic map of Serbia, as well as genetic-industrial classification of gemstone deposits and gemstone varieties.

Key words: gemstone, genetic-industrial classification, metallogenic localization, genetic types.

Introduction

Gemstones are a group of different minerals and rocks quite sensitive to personal taste and the aesthetic quality of not only raw material but the final processing as well. Gemstones are classified either a subgroup of non-construction industrial minerals (Dill 2010), a subgroup of deposits of industrial crystals (Vakanjac 1969), or a subgroup of industrial minerals (Kužvart 1984).

The search for gemstone deposits in Serbia has attracted very limited attention in the past, although opal and silicified wood from some localities were used in Neolithic time (Bogosavljević Petrović 2005; Bogosavljević Petrović & Marković 2014), as well as in the early Byzantine period, when in Justiniana Prima (Spieser 2012) amethyst and agate from the Rasovača deposit were used for mosaic as can still be seen today.

Geological prospection for gemstones in the second half of last century has been focused mostly on recording interesting locations observed during exploration of other mineral resources (metallic and non-metallic). In very rare cases extensive and detailed explorations were performed with estimation of ore reserves, like the most explored gemstone area in Serbia-Lece area, due to the Pb-Zn-Au deposit Lece that was explored and exploited during last half century or more. Despite officially explored deposits, production of gemstones has never begun. Overview of the exploration results and a list of all at that time known gemstone deposits was summarized by Vakanjac (1978), Malešević et al. (1985) and Ilić et al. (1998).

Regional prospection and novel studies of gemstones in Serbia restarted in 2002, mostly in the Lece volcanic complex and Fruška Gora Mt. (Ilić et al. 2004; Miladinović et al. 2005) but also on Avala and Kosmaj Mt. (Ilić et al. 2010).

The quality of raw gemstone material has been certified by lapidary processing techniques, and their attractiveness has been successfully tested in the Serbian market.

Geological setting and metallogenic zoning

The geological setting of Serbia is very diverse with numerous geological formations, some of them prospective regarding gemstone minerals and rocks (e.g., ophiolites, Tertiary acid to intermediate volcanic complexes, some granitoide complexes, etc.). The mineral resources of Serbia have recently been summarized by Jelenković et al (2008), but gemstones were not included, so this paper is mostly dealing with geological features significant for gemstone origin and localization.

The main geotectonic units of Serbia include (Dimitrijević 1997, Schmid et al. 2008, Chiari et al. 2011): The Adria-derived units (Dinarides), the Vardar zone, the Europe-derived Dacia Mega Unit (Serbo-Macedonian Massif and Carpatho-Balkanides), the mixed European and Adriatic-affinity Tisza Mega-Unit (completely covered by thick sedimentary rocks of the Pannonian basin in Serbia), and the Moesian platform with external foredeep (Fig. 1).

The Dinarides consist of the following units: East Bosnian-Durmitor Unit, Dinaric (External) Ophiolite Belt, and Drina-Ivanjica Unit. The East Bosnian-Durmitor Unit includes a Palaeozoic basement, covered by unmetamorphosed Triassic to Palaeogene neritic and pelagic carbonate sequences topped by widespread Late Cretaceous to Miocene siliciclastic foredeep deposits (Chiari et al. 2011). Anisian to Ladinian porphyrite is typical for that unit. Towards the east it is overthrust by the Dinaric or External Ophiolite belt (Dimitrijević 1997), made up of Jurassic ophiolite and sub-ophiolite melange. The Drina-Ivanjica Unit consists of Palaeozoic metamorphic complex overlain by Permian to Early Triassic shale and sandstone, and Middle Triassic to Early Jurassic predominantly carbonate sediments, followed by Middle Jurassic radiolarites. In the SW part of Serbia effusive Oligocene to Miocene magmatic rocks of calc-alkaline affinity (Cvetković et al. 2004; Schefer et al. 2010) occur occasionally.

The Vardar zone represents a complex assemblage of continental and oceanic-derived units (Chiari et al. 2011 and references therein). The oceanic-derived units consist of a sub-ophiolite melange overthrust by ophiolites with a metamorphic sole at its base. Metamorphic Adria-derived units of the Jadar-Kopaonik-Studenica areas are exposed below the oceanic-derived units (Zelić et al. 2010). The Europe-derived continental units include metamorphic and sedimentary rocks of the Sava zone (Ustaszewski et al. 2010). The whole Vardar zone is characterized by widespread intrusive and effusive Oligocene to Pliocene magmatic rocks of calc-alkaline affinity (Cvetković et al. 2004; Schefer et al. 2010).

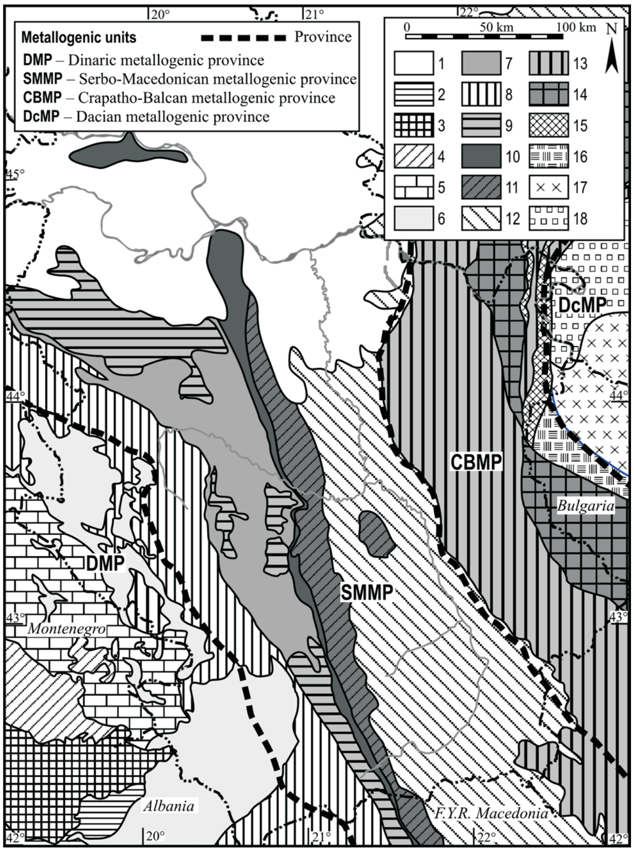

Fig. 1. Main geotectonic and metallogenic units of Serbia (modified after Dimitrijević 1997; Schmid et al. 2008; Chiari et al. 2011). **1** — Panonian Basin, **2** — Budva-Cukali Zone, **3** — High Karst Unit, **4** — Pre-Karst & Bosnian Flysch Unit, **5** — East Bosnian-Durmitor Thrust Sheet, **6** — Dinaric Ophiolitic Belt, **7** — Western Vardar Ophioliic Unit, **8** — Drina-Ivanjica Thrust Sheet, **9** — Jadar-Kopaonik Thrust Sheet, **10** — Sava Zone, **11** — Eastern Vardar Ophiolitic Unit, **12** — Serbo-Macedonian Unit, **13** — Getic Unit, **14** — Danubian Nappes, **15** — Ceahlau-Severin Unit, **16** — Central Balkan & Prebalkan Units, **17** — Moesian Platform, **18** — External Moesian Foredeep.

The Europe-derived Serbo-Macedonian Unit (as part of the Dacia Mega Unit) overthrust the Vardar zone. The Serbo-Macedonian Unit includes a medium- to high-grade metamorphic Neoproterozoic to Early Palaeozoic gneissic basement and sub-greenschist to epidote-amphibolite grade Palaeozoic successions. The Serbo-Macedonian Unit, particularly the southern part, was intruded by calc-alkaline intrusive and effusive magmatic rocks of the Oligocene age (Pamić & Balen 2001). Further towards the east, the Carpatho-Balkanides of the Dacia Mega Unit are subdivided into Supragetic/Getic nappes, the Ceahlau-Severin ophiolite-bearing nappes, and the Danubian nappes (Dimitrijević 1997; Matenco 2015). The Supragetic/Getic nappes consist of Neoproterozoic to Palaeozoic metamorphic rocks, which are unconformably overlain by Late Carboniferous to Permian continental clastics and Mesozoic rocks (Dimitrijević 1997; Iancu et al. 2005). The Mesozoic rocks include Middle Triassic carbonate platform followed by detrital Late Triassic to Early Jurassic strata, Middle Jurassic carbonates and radiolarites, Late Jurassic to Early Cretaceous pelagic series and Albian to Cenomanian Molasse-type deposits. Geticum was intruded by Palaeozoic granitoids and Late Cretaceous Timok magmatic complex and Ridan-Krepoljin zone effusives.

The Danubicum is composed of Neoproterozoic to Palaeozoic metamorphic rocks and Palaeozoic ophiolites (Zakariadze et al. 2006) in the Poreč-Stara Planina zone, unconformably overlain by Middle Carboniferous to Middle Jurassic continental clastics with subordinate carbonate rocks, Late Jurassic carbonate rocks and Albian to Late Cretaceous clastic to carbonate sedimentary rocks, occasionally with volcano-sedimentary sequences (Dimitrijević 1997).

The Ceahlau-Severin ophiolite-bearing nappes (Krajina zone) are relics of an oceanic rift (Matenco et al. 2010). The basement is made of ophiolite complex (Matenco 2015), while sedimentary cover consists of Early to Late Cretaceous Sinaia and Mokranje Flysch, and Miocene to Pliocene deposits.

The Moesian platform with external foredeep in Serbia is covered by thick Miocene to Pliocene and Quaternary sediments and, hence, of no interest regarding gemstones.

Gemstones in Serbia occur within four regional metallogenic units (Janković 1977, 1990; Janković et al. 1997; Jelenković et al. 2008): 1) Dinaric Metallogenic Province (DMP), covering western and south-western Serbia, 2) Serbo-Macedonian Metallogenic Province (SMMP) in the central part of Serbia, 3) Carpatho-Balkan Metallogenic Province (CBMP) in the eastern part of Serbia, and 4) Dacian Metallogenic Province (DcMP). The relationships between the metallogenic units and the main geotectonic units of Serbia are summarized in Figure 1. Smaller metallogenic units are marked in Figure 2.

Since the geology of Serbia is so diverse and complex, only lithological and structural units of great significance for

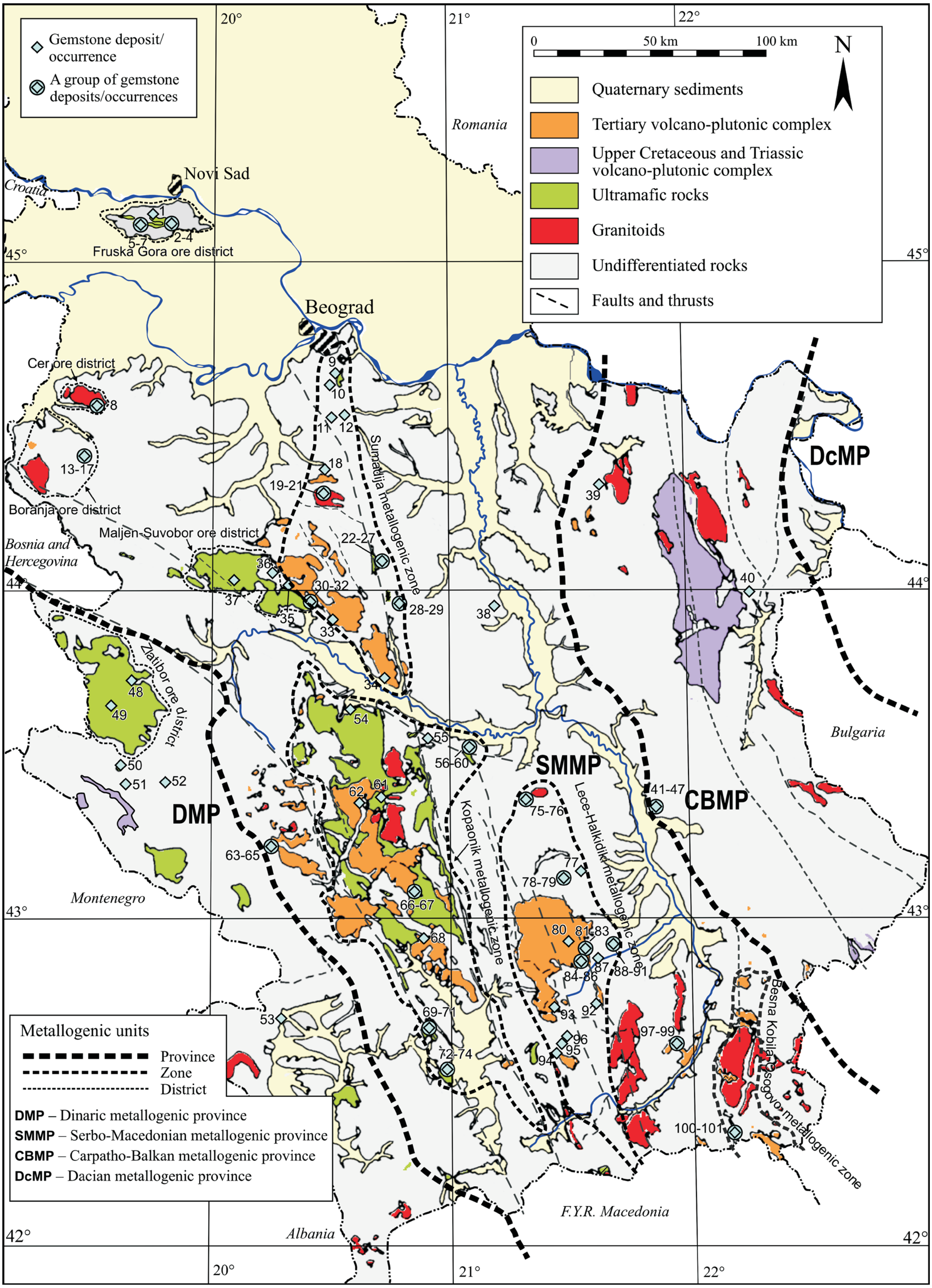

Fig. 2. Simplified metallogenic map of Serbia with distribution of gemstone deposits (numbers of deposits correspond to numbers in Table 1)

the formation and distribution of gemstone deposits are taken into consideration and presented in the map (Fig. 2).

Genetic-industrial classification of gemstone deposits

More than 150 gemstone mineral deposits and occurrences with different level of exploration are located in Serbia. At the current state of geological exploration and knowledge, 21 gemstones with numerous varieties and subvarieties, were selected and studied in more detail (Table 2).

Based on all available data genetic-industrial classification of most significant Serbian gemstones is proposed (Table 2). Serbian gemstones and their varieties are presented and classified according to their genetic type and corresponding productive geological formation.

Table 1: List of gemstone deposits and occurrences and their localities in Serbia.

No.	Gemstone deposits
1	Kozje brdo (agate; chalcedony – colourless, bluish, purple; jasper – brown red, quartz – rock crystal, carbonate-silica breccia and onyx)
2–4	A group of deposits in the eastern part of Fruška Gora: 2 – Neradin (carbonate-silica breccia and onyx, chalcedony – colourless, jasper – brown, serpentinite); 3 – Hopovo (agate, carbonate-silica breccia); 4 – Jazak (carbonate-silica breccia)
5–7	A group of deposits in the western part of Fruška Gora: 5 – Letenka (common opal, carbonate-silica breccia); 6 – Duge Luke (carbonate-silica breccia, chalcedony, jasper); 7 – Grabovo (common opal, quartz – rock crystal, jasper, carbonate-silica breccia)
8	A group of deposits in the eastern part of Cer Mt (beryl – aquamarine, schorl, quartz – rock crystal, morion, smoky quartz)
9	Pinosava-Resnik (landscape jasper)
10	Avala (serpentinite)
11	Babe (quartz – rock crystal, jasper)
12	Ropočevo (marble breccia)
13–17	A group of fluorite deposits near Krupanj: 13 – Ravnaja; 14 – Pantelići; 15 – Kućište; 16 – Jovanovići; 17 – Teletići
18	Kameniti Oglavak (common opal)
19–21	A group of deposits near Aranđelovac: 19 – Bukovik (beryl – aquamarine, quartz – rock crystal, morion); 20 – Vagan (beryl – aquamarine); 21 – Onjeg (schorl)
22–27	A group of deposits: 22 – Gaj-Lazine (chalcedony, jasper, common opal); 23 – Ugljarevac (chalcedony – colourless, carnelian; jasper; common opal); 24 – Varnica (jasper, colourless chalcedony); 25 – Ramaća (common opal, chalcedony); 26 – Dobrača (common opal, jasper, quartz – rock crystal, chalcedony, magnesite-silica breccia); 27 – Kovijanica (common opal, chalcedony)
28–29	A group of deposits: 28 – Vučkovica (chalcedony, agate, common opal, carbonate-silica onyx); 29 – Donja Vučkovica (chalcedony, common opal)
30–32	A group of deposit near Gornji Milanovac: 30 – Srezojevci (jasper, chalcedony – colourless, carnelian); 31 – Boblija (jasper – orbicular jasper, picture jasper; agate; chalcedony – carnelian, sard, colourless; common opal); 32 – Kremenac (jasper, chalcedony, common opal)
33	Kremenjača (agate, jasper – landscape and picture, chalcedony)
34	Sirča (carbonate-silica onyx, chalcedony)
35	Teočin (quartz – rock crystal, milky quartz)
36	Cvetin Vrh (jasper, chalcedony, common opal)
37	Tometino polje (picture jasper)
38	Lozovik (marble onyx)
39	Antina Čuka (listvenite, serpentinite, green quartz)
40	Rgotina-Jelašnica (agate)
41–47	A group of deposits near Niš: 41 – Rujnik, 42 – Kremenac, 43 – Crni vrh, 44 – Rujnik–Igralište, 45 – Siterak, 46 – Torina, 47 – Humska čuka (chalcedony, jasper, common opal)
48	Braneško Polje (dendritic opal, chalcedony)
49	Ribnica (common opal)
50	Barice (travertine onyx)
51	Drenovska reka (jasper)
52	Akmačići (jasper)
53	Banjica (marble onyx)
54	Lojanik (silicified wood)
55	Popina (jasper)
56–60	A group of deposits near Veluće monastery: 56 – Veluće, 57 – Pečeni grob, 58 – Žuti kamen, 59 – Ilijina glava, 60 – Punoševići (opal, jasper, chalcedony)
61	Koprivnica (fluorite)
62	Jarandol (howlite)
63–65	A group of common opal deposits near Duga Poljana: 63 – Šarski Potok, 64 – Šaransko Vrelo, 65 – Lazine
66–67	A group of deposits near Leposavić: 66 – Donje Jarinje, 67– Kremenjački Potok (common opal, chalcedony, jasper)
68	Trepča (quartz – rock crystal, rodochrosite)
69–71	A group of deposits in Drenica: 69 – Čikatovo, 70 – Baks (common opal, chrysoprase); 71 – Gladno Selo (silicified wood)
72–74	A group of deposits on Goleš Mt: 72 – Glavica (common opal – chrysopal, hony opal, milky opal, dendritic opal; chalcedony – chrysoprase), 73 – Medvece (opal – milky, cacholong), 74 – Mirena (common opal)
75–76	A group of deposits on Mt Jastrebac: Pribežička Kosa, Hajdučki Izvor (kyanite)
77	Dobrotić (beryl – aquamarine)
78–79	A group of deposits near Prokuplje: 78 – Rgaja, 79 – Čukara (kyanite)
80–83	A group of deposits: 80 – Gajtan–Crvodik (jasper, chalcedony); 81 – Bučumet (jasper, chalcedony); 82 – Bučumetska Padina (jasper, chalcedony); 83 – Kameno Rebro (chalcedony, jasper);
84–86	A group of deposits: 84 – Lece (quartz – amethyst); 85 – Rasovača (quartz – amethyst, agate, jasper); 86 – Vrtače (chalcedony, jasper);
87	Kladanci (jasper, chalcedony)
88–91	A group of deposits: 88 – Caričin Grad–Sekicol, 89 – Caričina–Mijajlica, 90 – Svinjarica-Dubrava, 91 – Svinjarički potok (chalcedony, jasper)
92	Sijarinska banja (marble onyx)
93	Mutivode (chalcedony, jasper)
94	Klobukar (chalcedony, common opal)
95	Crni kamen (chalcedony)
96	Beli Kamen (magnesite-silica breccia)
97–99	A group of deposits near Vranjski Priboj: 97 – Kremen I, 98 – Kremen II, 99 – Jovička reka (jasper, chalcedony)
100–101	A group of deposits near Gornji Stajevac: 100 – Surlica I, 101 – Surlica II (chalcedony, jasper)

Geology and mineralogy of selected gemstone deposits

Selected Serbian gemstone deposits have been described here in the shortest possible form, as the most representative ones for their genetic types. In numerous deposits in Serbia the dominant types of gemstones are silica minerals.

The quality of raw minerals from selected deposits was tested using lapidary cutting and polishing techniques.

Table 2: Genetic-industrial classification of gemstones in Serbia.

Genetic type	Ore-bearing geological formation	Host rock	Deposits and occurrences	Gemstones
I Hydrothermal	1. Jurassic ultramafic rocks	Serpentinite	Kozje Brdo (Fruška Gora)	Chalcedony (colourless, purple, bluish); agate, carbonate-silica breccia and onyx, serpentinite
			Ramaća (Kragujevac)	Opal (different coloured varieties, multicoloured)
			Vučkovica (Kragujevac)	Magnesite-dolomite-silica breccia (variegated); agate (bluish); serpentinite-magnesite breccia
			Boblija, Kremenac (Gornji Milanovac)	Jasper (variegated, orbicular); chalcedony (carnelian, different colour varieties); opal (green)
			Murgulska Reka (Lukovska Banja)	Ankerite (azure blue)
		Harzburgite	Goleš – Mirena	Opal (brown)
			Dobroševac	Opal (different colour varieties); chalcedony (different colour varieties)
		Serpentinite	Kuna Ljuget (Podujevo)	Opal (green and brown)
			Klobukar (Novo Brdo)	Opal (brown); chalcedony (different colour varieties)
			Antina Čuka (Kučevo)	Quartz (green), serpentinite
			Gaj – Lazine (Kragujevac)	Opal (different colour varieties) Chalcedony (different colour varieties)
	2. Tertiary volcanic complexes	Andesite	Rasovača (Lece volcanic complex)	Amethyst, agate, jasper
			Lece (Lece volcanic complex)	Amethyst, agate, jasper
			Bučumet, Bučumetska padina, Gajtan-Crvodik (Lece volcanic complex)	Jasper and jasper-chalcedony (diverse colour varieties)
		Dacite	Kremenjača (Borač-Kotlenik volcanic complex)	Agate, chalcedony (bluish and pinkish), jasper (picture jasper, different colour vaieties),
			Kameniti Oglavak (Venčane)	Opal (different colour varieties)
	3. Tertiary sediments	Sandstone, conglomerate	Popina (Vrnjačka Banja)	Jasper (different colour varieties)
		Dolomitic limestone, marlstone	Magnesite deposit Beli Kamen (Strezovce)	Silica (quartz-chalcedony) breccia (black); magnesite-silica breccia; silicified dolomite (brown)
		Marlstone, shale	Jarandol	Howlite
	4. Mesozoic sediments	Dolomite	Teočin (Gornji Milanovac)	Quartz (rock crystal, milky quartz)
	5. Palaeozoic metamorphic rocks	Schists and marbles	Trepča (Pb-Zn deposit Stari Trg)	Quartz (rock crystal), calcite, rodochrosite
	6. Plutonic complexes of Palaeozoic to Tertiary age	Limestone	Ravnaja, Pantelići, Kućište, Jovanovići, Baletići (Krupanj)	Fluorite
II Pegmatite-pneumatolitic	1. Plutonic complexes of Palaeozoic and Cainozoic age	Pegmatite (Tertiary)	Parlog (Cer), Bukovik (Aranđelovac)	Beryl (aquamarine), tourmaline (schorl), quartz (rock crystal)
			Cer, Rašće, Onjeg (Aranđelovac),	Tourmaline (schorl)
		Pegmatite (Palaeozoic)	Rekovac, Staro Selo (Kragujevac), Komša (Kučevo)	Quartz (rock crystal)
			Šumane, Ornica (Lebane), Bujanovac	Tourmaline (schorl)
III Infiltration	1. Weathering crust on ultramafic rocks of Palaeogene age	Harzburgite	Goleš - Glavica	Opal (chrysopal, dendritic opal, different colour varieties), chrysoprase
			Medvece	Opal (milky white, dendritic)
			Baks (Drenica)	Opal (green, brown, dendritic)
			Gladno Selo (Drenica)	Silicified wood
		Serpentinite	Ugljarevac (Kragujevac)	Opal (different colour varieties); chalcedony (grey with brown specks)
			Dobrača (Kragujevac)	Chalcedony (brown-black); silicified magnesite (multicoloured)
			Veluće (Trstenik)	Opal (different colour varieties); chalcedony (different colour varieties)
			Mataruge (Mataruška Banja)	Opal (different colour varieties); chalcedony (different colour varieties)
			Lojanik (Mataruška Banja)	Silicified wood
IV Sedimentary	Placer	Alluvial sediments	Lešnička reka (Cer)	Beryl (aquamarine)
		Elluvial, deluvial and proluvial sediments	Vrtače, Kameno Rebro (Lece volcanic complex)	Jasper (multicoloured), carnelian, jasper-chalcedony (multicoloured)
			Parlog (Cer)	Beryl (aquamarine); quartz (rock crystal, smoky quartz)
			Klobukar (Novo Brdo)	Opal (brown); chalcedony (multicoloured)
V Metamorphic	1. Crystalline schists of Precambrian and Palaeozoic age	Gneiss and micaschist	Crni Vrh (Jagodina), Pribežička Kosa, Hajdučki Izvor (Jastrebac), Rgaja, Čukara (Prokuplje),	Kyanite
			Ogošte (Gnjilane)	Garnet (almandine)
		Metamorphogene pegmatites	Dobrotić (Prokuplje)	Beryl-aquamarine

Kozje Brdo

One of the most significant regions with gemstone deposits in Serbia is the Fruška Gora ore district, located on the Fruška Gora Mountain. Seven gemstone deposits have been found in this district (Antonović et al. 1985; Antonović 1996; Ilić et al. 2002; Miladinović et al. 2005). Apart from the aforementioned there are numerous, still insufficiently explored gemstone mineralizations.

The Kozje Brdo deposit, as well as the majority of other Fruška Gora gemstone deposits, is hosted by the Fruška Gora ultramafic massif. That part of ophiolite underwent intensive polyphase tectonic deformation (mainly disjunctive), serpentinization, hydrothermal alteration (primarily listvenitization) and mineralization (mainly carbonates and silica). The Kozje brdo deposit is related to a regional E–W fracture zone, namely the Srem dislocation (Čičulić-Trifunović & Rakić 1977). Along this fracture zone intensive tectonic activity enabled subsequent hydrothermal solutions that formed gemstone minerals in the form of veins, veinlets, nests and irregular ore bodies. Intermittent tectonic movements brecciated previously formed gemstone ore bodies and surrounding rocks, and caused formation of new generations of silica and carbonate minerals. Hydrothermal activity in this region was closely interrelated with Upper Oligocene–Miocene tectonic activity and intermediate dacite-andesite and latite volcanism (Knežević et al. 1991; Kovács et al. 2007; Vasković et al. 2010; Cvetkov et al. 2012).

The Kozje Brdo gemstone deposit is composed of chalcedony (colourless, bluish, purple, agate), quartz (rock crystal and milky quartz), jasper (mainly brown), magnesite, dolomite, calcite and ankerite. Microcrystalline magnesite bodies formed at first, but have been subsequently repeatedly tectonically broken and therefore intensely brecciated. Open voids were filled with carbonate and silica minerals in the form of parallel bands (onyx), concentric bands (agate), separate veins and veinlets and as a cement in breccia. The last mineral generation is made of quartz (rock crystal and milky quartz) and chalcedony.

The dominant rock in this deposit is carbonate-silica breccia, a magnesite-dolomite-ankerite rock with a high content of silica. The basic colour of this rock is yellow-brown with lighter and darker colour varieties. The carbonate-silica breccia can also be used as an ornamental or decorative stone at the same time.

Carbonate-silica onyx, often accompanying agate, consists of parallel bands of mostly carbonate minerals (dolomite, calcite, ankerite) alternating with silica minerals (chalcedony and quartz). Silica also impregnates carbonate minerals giving to the carbonate part of onyx a slightly higher hardness. Band colours range from brown to pale green, yellow and white.

Agate is mainly a constituent of carbonate-silica breccia along with carbonate-silica onyx but it also forms separate veins outside of the main ore body in host serpentinite. Kozje Brdo agate is characterized by alternating bands of colourless, white and bluish bands. Rarely, some agate bands are made of microcrystalline quartz. In the central parts of concentric agate bands, quartz rock crystal and/or brown to red jasper is sometimes formed. Beside typical concentric agate, tube agate occasionally occurs.

Kozje brdo jasper is mostly found together with carbonate-silica onyx and agate in the central parts of symmetrically filled voids. Jasper usually forms several centimetres thick veinlets, but occasionally those veinlets pass into 10 cm thick veins. Sometimes jasper forms small isolated nests of decimetre dimensions.

The colourless and bluish chalcedonies occur in the form of irregular veinlets, stockworks and nests (geodes) of decimetre dimensions. Colourless chalcedony variety is more frequent then bluish, which is usually found in deluvial placers. Both colourless and bluish chalcedony from Kozje brdo, if properly cut *en cabochon,* resemble moonstone.

Purple chalcedony can be found along far eastern border of the Kozje Brdo deposit forming veins and stockwork in serpentinite. The colour of this gemstone displays various shades of purple and bluish purple.

Very rarely and only in the southern part of the deposit (placers) translucent yellow-brown chalcedony was discovered.

Quartz rock crystal is formed in cavities within veins and nests with usually small crystals but uniform in size (around one centimetre in length). Larger quartz druses can also be found, with crystals reaching the length of 5 to 6 cm.

Ramaća

One of the typical gemstone deposits in the Šumadija metallogenic zone is Ramaća (Bogosavljević Petrović 2005). This deposit consists of opal forming a significant mass stretching in a N-S direction on the surface of around 18 ha. Opal masses are located in tectonically broken and hydrothermally altered serpentinite. This opal is common opal with conchoidal fracture, vitreous lustre which on fractures tends to grade into greasy, waxy and resinous lustre. Ramaća opal tends to be very brittle particularly if found close to the surface. Nevertheless, there are sufficient quantities of rough crack-free opal. It is possible that increased brittleness of Ramaća opal is partly caused by inadequate previous exploitation. The most common colour of Ramaća opal is green (grass green) in various shades, brown (various shades), red, variegated. Quartz and chalcedony can be sporadically found in filled cracks. Intensely opalized serpentinites are also very attractive and suitable to be used as a gemstone.

Kremenjača

The Kremenjača gemstone deposit is located in the SW part of Borač volcanic complex, a part of Šumadija metallogenic zone. This complex is a part of the Rudnik-Borač-Kotlenik Late Palaeogene-Neogene volcanic formation (Cvetković et al. 2000). The oldest surrounding rocks are serpentinites, which are mostly overlain by Tertiary volcanic rocks. The central part of the Kremenjača hill is made up of dacite and dacite tuff. The tectonic setting of the site is marked by N-S and NNW-SSE trending faults (Kurešević et al. 2014). Silica gem minerals at Kremenjača form veins, small nests and irregular ore bodies of hydrothermal origin along with typical volcanic agate as defined by Moxon (2009).

Kremenjača gemstone deposit is made of jasper, chalcedony (bluish, pale pink), sard, onyx, and agate. Jasper is differently coloured: brown (various shades), dark red, purple, grey and green. Sometimes it grades into picture jasper and even to imperial jasper subvariety. Chalcedony is bluish and pale pink. Orange-red carnelian and brown sard are found only as small fragments in delluvial deposits. In onyx, white translucent to opaque bands alternate with translucent to transparent brown-coloured bands (Kurešević et al. 2014). The most common agate in Kremenjača is translucent, colourless, bluish and pale pink with white bands. It was also recorded that "fish agate" was found (Malešević 1984, in Ilić et al. 1998).

Boblija

This gemstone deposit is located on the Boblija hill near Gornji Milanovac in a relatively small mass of intensely tectonized and hydrothermally altered (silicified) ultramafics. Intense Late Palaeocene-Neogene volcanic activity is typical for the wide area, causing hydrothermal origin of gemstones (Cvetković et al, 2000). Boblija is the far easternmost part of the Maljen-Suvobor ultramafic complex which is intersected by numerous fractures of different categories and size, the most significant being of NW–SE orientation (Filipović et al. 1971).

The Boblija deposit is represented by a large irregular horizontal plate-like ore body and numerous veins and veinlets in hydrothermally altered (silicified and limonitized) serpentinite (Ilić et al. 2006). Both horizontal ore body and veins and veinlets are formed by silica minerals: jasper — variegated and multi-coloured (picture jasper), orbicular jasper (Fig. 3G–J, Fig. 4E–F), colourless and bluish chalcedony, carnelian, sard and agate (Fig. 4G). Most frequently, different colours gradually change over small distances. Darker jasper shades (black, brown, dark red) alternate with lighter shades (light red, orange, yellow, grey, white). Orbicular jasper has very different body colour while orbs are usually white or light yellow. In voids, around orbicular spheres, botryoidal aggregate surfaces are occasionally covered by small quartz crystals (up to 2 mm in length). In some orbicular jaspers, agate zone continues over lightly coloured bends or spherulitic zone, with alternation of colourless and brown chalcedony.

Cer Mountain

The Cer granitoid complex is located in the N-W part of Serbia along the junction between the southern Pannonian Basin and Jadar-Kopaonik thrust sheet. It is a complex laccolith-like intrusion (~60 km^2) of four rock-types (Koroneos et al. 2011): metaluminous I-type quartz monzonite/quartz monzodiorite (QMZD); peraluminous S-type two-mica granite (TMG), which intrudes QMZD; Stražanica granodiorite/quartz monzonite (GDS); and isolated mafic enclaves (ME), found only in QMZD. The same authors reported the age of not later than 21 Ma for QMZD and estimated the age of GDS and TMG at 18 and 16 Ma, respectively.

Gemstone mineralization is related to granite-porphyrite, lamprophyre and aplite-pegmatite. Gemstone varieties include beryl (aquamarine type), tourmaline, rock crystal, smoky quartz, morion and garnets.

Quartz and beryl from pegmatites are located at Parlog and Mirkovača. As well as occurring in situ they have also accumulated in elluvial placers. Beryl from Mirkovača is most commonly blue (aquamarine) and rarely light green in colour. Aquamarine crystals of gemstone quality are up to 3–4 cm in size. They are usually translucent with nice blue colour suitable for plain cut (*en cabochon*, Schuman 2011). Apart from these translucent, transparent clear crystals of both blue and green aquamarine colour are present. They are quite suitable for faceting.

After destruction of primary ore bodies, placer deposits were formed with alluvial placers being economically the most significant. Alluvial sediments of the Milinska River are rich in garnets (pyrope and almandine) which are, unfortunately, usually very small and only occasionally reaching size suitable for gemstone cutting. Significant alluvial gemstone placers are those in the valleys of the Kamenička and Lipovačka rivers.

Lojanik

The silicified wood of Lojanik is both a gemstone deposit and a Neolithic archaeological site (Bogosavljević Petrović et al. 2014). Lojanik is a hill on the outskirts of the Mataruška Banja thermal spa, 8 km SW of Kraljevo town. Silicified wood occurs within Miocene conglomerates that were deposited in the southern part of the Zapadna Morava basin, along the tectonic contact with the large serpentinite body of Mt. Stolovi (Pavlović et al. 1977).

Lojanik occupies a space of some 5 ha with silicified wood in the form of twigs, branches and even logs. Based on anatomical research (Joksimović et al. 1997) the silicified wood has the structure of fir (*Abies* sp.). The predominant form of silica in silicified wood is opal, while chalcedony is less frequent. The wood structure is usually well preserved (in sawn and polished slabs wood nodes are easily noticeable — Fig. 4J). In some specimens it is very hard to distinguish macroscopically the original structure in cross-sections, although the outer shape of wood is completely preserved. The colour of silicified wood is usually brown, black, grey and white. Silicified wood is mostly opaque to slightly translucent. Common opal which occurs separately (not related to silicified wood) is generally of the same colour as silicified wood with the exception that they can also be green (grass green — Fig. 4C). Cutting and polishing of both silicified wood and opal has proven that they can be lapidary raw material of good quality.

Goleš Mt. (Glavica deposit)

In weathering crust of the Goleš ultramafic massif, veins and veinlets of opal and chalcedony of infiltration origin occur in the Glavica deposit. This is, at the same time, Ni-Co and stockwork magnesite deposit.

The deposit is located in the furthest southwestern part of the Goleš peridotite massif within a larger relic of weathering crust on peridotite (harzburgite). The thickness of the weathe-

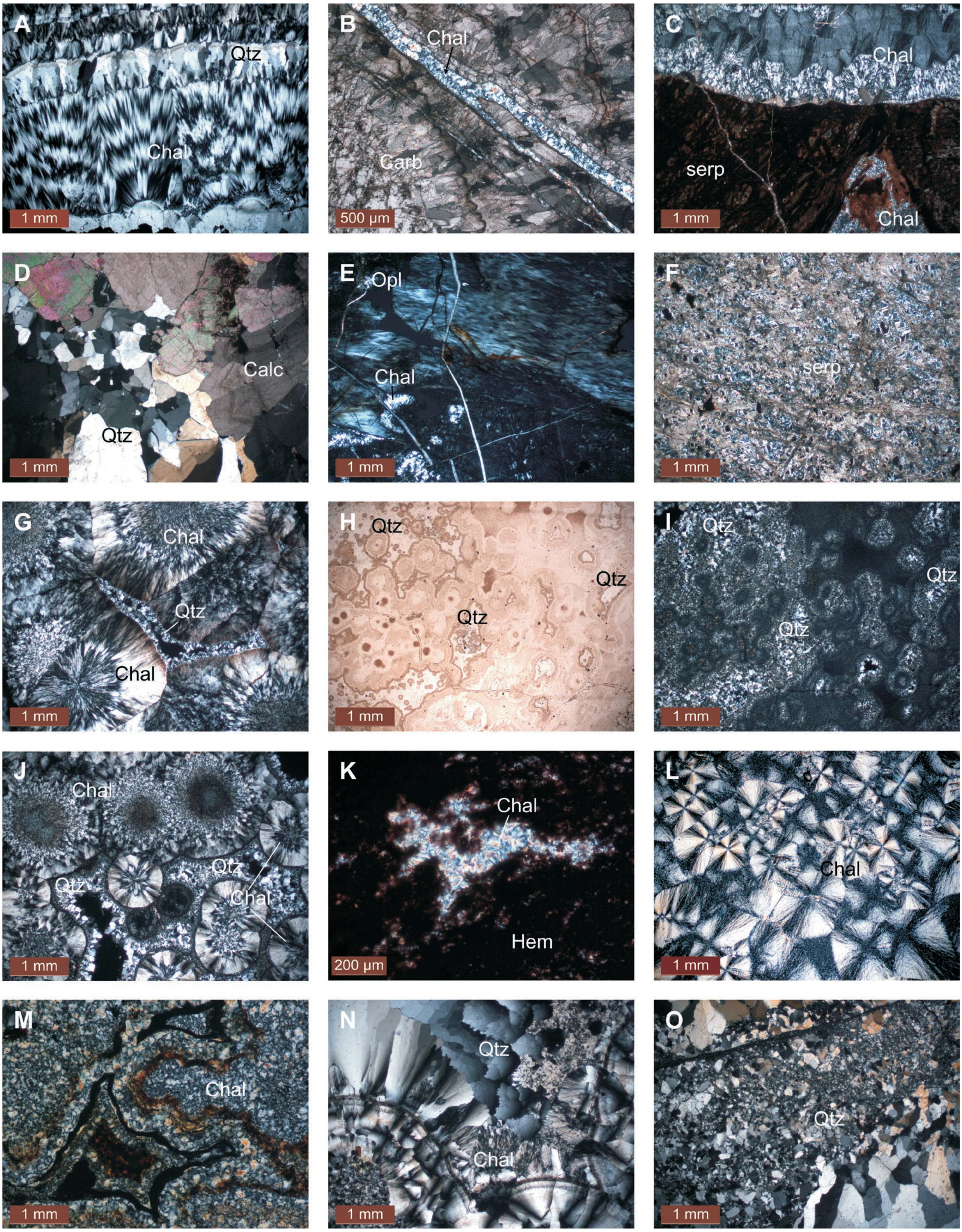

Fig. 3. Gemstone thin section photomicrographs: **A** — agate from Kozje Brdo (xpl); **B** — carbonate-silica onyx from Kozje Brdo (xpl); **C** — agate from Hopovo (xpl); **D** — carbonate-silica breccia from Letenka (xpl); **E** — silicified serpentinite — opal from Letenka (xpl), **F** — serpentinite from Neradin (xpl); **G** — orbicular jasper from Boblija — brown jasper with white orbs (xpl); **H** — orbicular jasper from Boblija — white jasper with dark grey orbs (ppl); **I** — orbicular jasper from Boblija — white jasper with dark grey orbs (xpl); **J** — orbicular jasper from Boblija — red jasper with differently coloured orbs (xpl); **K** — red jasper from Gajtan–Crvodik (xpl); **L** — chalcedony from Put za Vlasovo (xpl); **M** — multicoloured jasper–chalcedony from Vrtače (xpl), **N** — agate from Rasovača (xpl); **O** — amethyst from Rasovača (xpl); Carb — carbonate minerals; Chal — chalcedony; Hem — hematite; Opl — opal; Qtz — quartz; serp — serpentinite. (A–F — Fruška Gora ore district; G–J — Šumadija metallogenic zone; K–O — Lece-Halkidiki metallogenic zone)

ring crust ranges from 30–60 m with a clear vertical zonation. From the surface downwards the following zones occur: 1) zone of quartz-opal masses, 2) goethite zone, 3) smectite (nontronite) zone with nickel silicates and 4) zone of partially disintegrated harzburgite (Maksimović et al. 1994).

Gem minerals (opal and chalcedony) occur in the form of small veins, with thickness of 1–8 cm in weathering crust zones 2, 3 and 4 (Malešević et al. 1985). The most attractive of gem varieties from the Glavica deposit are chrysoprase and praseopal (Fig. 4K). Their colour originates from admixtures of Ni-silicates and Ni-sepiolite (Maksimović et al. 1994). Both chrysoprase and praseopal have the same colour and it is impossible to distinguish them macroscopically. Praseopal is much more common than chrysoprase. Some praseopal is hydrophane and can change colour and transparency with loss of water.

Apart from green opal and chalcedony, particularly interesting varieties are dendritic opals (Fig. 4L), with white, green and bluish base colour. They can be opaque (milky white with manganese dendrites), translucent to almost transparent. Other opaque opals can display several shades of brown, and yellow. Chalcedony usually has very attractive orange colour variety.

Lapidary processing of gem minerals (opal and chrysoprase) from the Glavica deposit revealed very good results. As expected for this type of gemstone raw material, the best form of cutting is *en cabochon* whether in standard (round, oval, rectangular, Fig. 4K) or free designer forms (Fig. 4L).

Lece

One of the most significant gemstone-bearing regions in Serbia is the Lece volcanic complex which is situated in the southern part of Serbia and covers an area of over 700 km^2. The most characteristic deposits of this area are: Rasovača, Bučumet, Vrtače and Kameno Rebro. This volcanic complex, formed as a result of Tertiary volcanic (intermediate) activity, is a part of the Serbo-Macedonian metallogenic province or Lece–Chalkidiki metallogenic zone (Janković, 1990; Serafimovski, 2000). It comprises mostly andesite rocks and their pyroclastic equivalents (Pešut 1976).

The gemstone deposits of the Lece volcanic complex are represented by hydrothermal (epithermal quartz-brecciated zones and quartz/agate veins and telethermal deposits — siliceous sinters and volcanic agates), as well as elluvial, delluvial, prolluvial and alluvial placers, which are created by degradation of the primary endogene deposits (Miladinović et al. 2010; Miladinović 2012).

The mineral composition of gemstone is mainly represented by quartz/amethyst (Fig. 3O), chalcedony (“length-fast” and “length-slow”, Fig. 3L and N) and jasper (mixture of quartz and chalcedony, Fig. 3K and M). Numerous subvarieties (regarding colour and textural characteristics) of chalcedony (agate, carnelian, sard, black chalcedony, blue chalcedony, picture, and moss), jasper (red, brown, picture jasper in variegated colour variations, landscape jasper) and quartz (amethyst and rock crystal) were determined (Miladinović 2012).

Rasovača deposit belongs to the group of hydrothermal (epithermal) gemstone deposits spatially related to brecciated quartz veins. This is one of most important deposits in the Lece volcanic complex. Gemstones in this deposit occur in the same fracture zone 6 km long together with Pb, Zn, Ag and Au mineralization (Lece underground mine). Intensive tectonic activity made space for the circulation of hydrothermal solutions which deposited not only galena, sphalerite, pyrite and gold but gem minerals as well. Precious silica minerals are represented by amethyst, amethyst-agate, and agate. Red jasper appears only in small quantities. Amethyst is characterized by a fine dark purple colour (Fig. 4M). Agate is represented by concentric bands of white, grey, bluish, yellow, brown and red chalcedony (Fig. 4N).

Bučumet is the best preserved primary telethermal (siliceous sinter) deposit within the Lece volcanic complex. In the succession of andesite lava flows and pyroclastic material, silica masses formed as plate-like ore bodies. These masses are the result of depositing silica around thermal springs and geysers. Siliceous masses made of fibrous chalcedony, granular quartz and relict opal, have very heterogeneous colour varieties. Basically, a very wide range of colours appears in a short range. Chalcedony is represented by both variegated and uniform colour varieties of white, bluish, grey, brown, red and black. Jasper is yellowish-brown to reddish-brown.

The Vrtače and Kameno Rebro deposits are placer type deposits. While Vrtače is an eluvial deposit in pyroclastic material with partially preserved primary ore body, Kameno Rebro is a completely delluvial deposit formed outside the volcanic complex in the surrounding Proterozoic metamorphic complex. Gem minerals which occur in these two deposits are of the same type as in the Bučumet — chalcedony and jasper (Fig. 4O). It is assumed that the material in the Kameno Rebro deposit originates mostly from the eroded part of the Bučumet deposit.

Discussion and conclusion

Although Serbian gemstone resources are insufficiently explored, over 150 gemstone deposits and occurrences have been recorded, most of which are made of silica minerals. They belong to gemstone mineral resources of lower market value. Mainly ore bodies are close to the surface and exploitation of some of deposits could start very fast. The cause of the fact that not a single mine is operating at the moment lies not only in lack of tradition in the field but also in rather unsupportive legislation.

For its size Serbia has very diverse geology which enhances its gemstone perspective. Almost every big geotectonic unit has the potential to yield gemstone deposits of different genetic types. Five genetic types of gemstone deposits determined so far in Serbia are: hydrothermal, pegmatite-pneumatolitic, infiltration deposits within weathering crust of ultramafics, sedimentary — placer and metamorphic deposits.

The Tertiary volcano-plutonic complexes of the Serbo-Macedonian metallogenic province are of major importance with numerous hydrothermal gemstone deposits (mainly silica minerals). Those complexes usually form metallogenic subunits of Serbo-Macedonian province: Lece-Chalkidiki

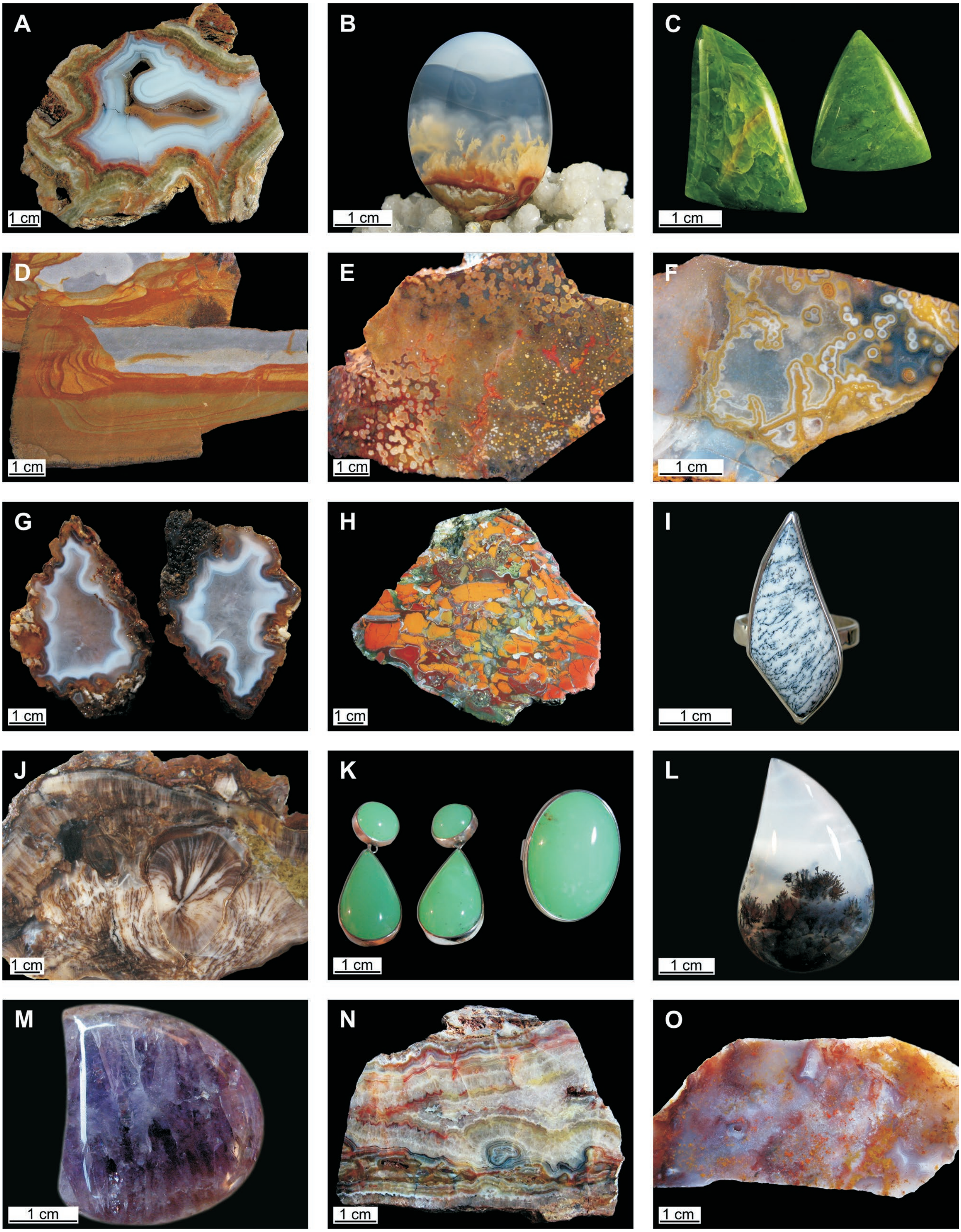

Fig. 4. Selection of partly and completely processed gemstones from Serbia: **A** — agate bearing carbonate-silica breccia (Kozje Brdo); **B** — agate (Kozje Brdo); **C** — green opal (Lojanik); **D** — landscape jasper (Avala); **E–F** — orbicular jasper (Boblija); **G** — agate (Boblija), **H** — picture jasper (Tometino Polje); **I** — dendritic opal (Braneško Polje); **J** — silicified wood (Lojanik); **K** — chrysoprase (Glavica); **L** — dendritic opal (Glavica); **M** — amethyst (Rasovača); **N** — agate (Rasovača); **O** — jasper–chalcedony (Vrtače).

zone, Šumadija zone, Besna Kobila-Osogovo zone and Kopaonik zone. The most interesting volcanic complex regarding the number of discovered gemstone deposits is the Lece andesitic massif.

Ultramafic rocks in the Jurassic ophiolite complexes of the Vardar zone possess significant gemstone resources potential, confirmed by good results from geological exploration. There are especially numerous gemstone deposits in Šumadija metallogenic zone of Serbo-Macedonian metallogenic province, but the entire Vardar zone of the Serbo-Macedonian province has a good potential in the domain of ultramafic complexes. Significant gemstone deposits are discovered in three serpentinite zones of the Fruška Gora district as well as in the Šumadija metallogenic zone and Kopaonik metallogenic zone. The underexplored but very interesting and rather large ultramafic complex of Maljen-Suvobor has good quality jasper and chalcedony deposits. The ultramafic complexes of the Dinaric metallogenic province possess the highest potential for gemstone deposits. The Zlatibor ultramafic massif is the most interesting in that province.

The granitoid intrusives in Serbia are present in all metallogenic provinces except the Dacian. The age of those intrusives ranges from Permo-Carboniferous to Tertiary. Cer and Bukulja yielded the best gem quality minerals (beryl — aquamarine) within pegmatites and related placer deposits.

The Carpatho-Balkan metallogenic province seems to be the least promising based on the number of so far discovered deposits within it. This is in strong contrast to the positive magmatic, structural, lithological and other metallogenic criteria, suggesting high potential for gemstones. The reason for the small number of gemstone localities is that gemstone prospecting has never been done in eastern Serbia. Another reason that speaks in favour of better gemstone possibilities in that part of Serbia is the existence of agate deposits in the Romanian and Bulgarian part of the Carpatho-Balkan metallogenic province (Iancu et al. 2009; Cincov & Banusev 2010).

We consider this metallogenic analysis of Serbian gemstone deposits and occurrences as a good starting point for further metallogenic studies in Serbia as well as in neighbouring countries, especially in those that share the same metallogenic units. Based on the current level of exploration we can establish several similar gemstone deposits in the Carpatho-Balkan metallogenic region, particularly for the most abundant type of Serbian gemstone mineral resources — silica gemstone minerals. There is a high level of congruence between infiltration type deposits of opal formed in weathering crust on ultramafics: Glavica at Goleš Mountain in south Serbia and Hodkovce in eastern Slovakia (Illášová & Spišiak 2010). Other good examples are the epithermal jasper deposits in Tertiary andesites: Magura Hill in Southern Apuseni Mountains in Romania (Constantina & Pop 2003) and Bučumet and Vrtače in Lece volcanic complex in Serbia.

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